Preliminary Designs of Traveling Screens to Collect Juvenile Fish

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UNITED STATES DEPARTMENT OF THE INTERIOR
U.S. FISH AND WILDLIFE SERVICE
BUREAU OF COMMERCIAL FISHERIES

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United States Fish and Wildlife Service
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FOREWORD

For many years biologists and engineers have been studying the problem of safeguarding juvenile salmon, shad, and striped bass from destruction in rivers that have hazardous hydroelectric or irrigation developments. As part of their research, they have studied the possibility of deflecting fish from their normal routes to alternate routes around the hazardous areas. Numerous methods of deflecting fish have been examined, such as bands of rising bubbles, curtains of hanging chains, electrical stimuli, lights, louvers, sound, and water jets. These methods were efficient under certain circumstances but were never completely reliable.

Notwithstanding the extensive and imaginative research, all fish guiding or deflection devices in use today are burdened with one or more of the following disadvantages: (1) high cost, (2) insufficient guiding efficiency, (3) mechanical limitations where the depth is great, the volume of water large, or the cross-sectional area of the canal or stream of extreme size, (4) excessive loss of head, (5) limitation in safely guiding or collecting not only fry but eggs (of striped bass and shad), (6) need for frequent adjustments to compensate for changes in flow volume, and (7) excessive maintenance.

The traveling screens described here were developed to overcome these disadvantages. A traveling screen may be generally described as a conveyor belt placed on edge diagonally across the path of juvenile fish migrating downstream. Young fish that approach the screen tend to avoid it as they continue downstream and thus are guided into a bypass at the downstream end of the structure.

Since 1965, biologists and engineers of BCF (Bureau of Commercial Fisheries) have developed and tested a series of six experimental traveling screens; another is in the design stage. The early models were not completely reliable, and fish were killed or damaged. The designs had to be improved.

The developments reported in this Special Scientific Report - Fisheries have greatly encouraged those who have to contend with the fishery problems arising from the multiple use of our great river systems. Perfection of fish protective devices will help eliminate one of the serious obstacles to the maintenance of stocks of fish.

Charles H. Meacham

Charles H. Meacham, Commissioner
U.S. Fish and Wildlife Service

INTRODUCTION

This report describes the design and operation of models I, II, and V. No report has been prepared on model III--the differences in design between it and model II were not great enough to warrant a separate report. Models IV and VI have been tested, and reports describing their features and operation are being prepared.

The basic design for model I was taken from that developed by the Fisheries Research Board of Canada during an investigation with traveling cables and a chain. BCF experiments on model I indicated a need to eliminate the drag created by the screen as it returned upstream through the water. This change was accomplished in model II by raising the screen clear of the water on its return upstream.

Model III, installed and tested within the Maxwell Canal (Hermiston, Oreg.) during 1966, had some improvements over model II, particularly in design of the carriage, track, and drive systems.

The step from model III to IV was significant from the standpoint of design and size of structure--the carriage and track systems were drastically changed, and the screen had to be made larger and stronger to handle flows that were 10 times greater than those handled by model III.

Model V represented a complete change in design and incorporated such features as a cable-suspension support structure, cantilevered screen panels to resist water forces, and replaceable panels in lieu of continuous screen belting.

CONTENTS

Page

Traveling screens, for collection of juvenile salmon (Models I and II), by Daniel W. Bates and John G. Vanderwalker 1

Introduction 1

Traveling screen 1
Design 1
Drive unit 1
Tracking unit 1
Screen belt and supports 1

Operating 3
Model I 3
Model II 3

Method of testing screen 4
Description of flume 4
Bypass 4
Test fish 4

Efficiency of the screen 4

Advantages of the screen 5

Literature cited 5

Design and operation of a cantilevered traveling fish screen (Model V), by Daniel W. Bates, Ernest W. Murphey, and Earl F. Prentice 6

Introduction 6

Description of traveling screen 6
Structural design 7
Suspension system 8
Torque tube and cables 8
Track design and support 9
Mechanical aspects 10
Drive system 10
Bull wheels 10
Haul line 10
Screen support system 10
Carriages 10
Stiff-legs 10
Netting and attachment 10
Bypass design 11

Operation of traveling screen 11
Rate of travel 12
Loss of head 12
Efficiency of deflection 12
Self-cleaning capabilities 13
Bypass 13

Effectiveness of traveling screen 14

Summary 14

Literature cited 15

Traveling Screens for Collection of Juvenile Salmon (Models I and II)

By

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ABSTRACT

Two horizontal traveling screens were designed and operated for 2 years at the Carson National Fish Hatchery, Carson, Wash. Deflection efficiencies were 100 percent in 37 tests of over 11,000 juvenile coho, Oncorhynchus kisutch, and chinook salmon, O. tshawytscha. The screens demonstrated their potential capacity to divert young salmon moving downstream.

INTRODUCTION

This paper describes the fabrication, operation, and efficiency of two horizontally traveling screens (models I and II). The screens are similar to the deflection device described by Brett and Alderdice (1958) in which fish were guided to a collection area with traveling cables. We used an endless screen belt instead of cables.

TRAVELING SCREEN

In this section the general design of the screens will be discussed, followed by the major features of the design--the drive unit, the tracking unit, and the screen belt and supports--which will be described in detail.

Design

The diagrammatic structure of the first experimental traveling screen (model I) is shown in figure 1. The fish are drifting downstream tail first. The screen, which resembles a conveyor belt on edge, was designed to return upstream through the water, but the extensive drag led to the development of a second screen in which return travel would be above and out of the water. This second screen (model II), built several months later, closely resembled model I except for the return structure. The following sections apply to both models and describe the drive units, tracking units, and endless screen belt and supports.

Drive Unit

The drive unit (fig. 2) consisted of a variable-speed d.c. motor and reduction gear, pocket sheaves, and a drive chain. A 1-hp. motor with a 10-170-r.p.m. reduction gear was used in both systems. A pocket sheave with a 56.5-cm. circumference, which accommodated a 6.8-mm. hand chain, was mounted on the drive shaft of the reduction gear. The maximum speed attained by the chain was 1.5 m.p.s. (meters per second).

The pocket sheave on the drive shaft, like the other sheaves, had two notches cut in the bottom rim to allow the hangers that supported the screen to pass around it. Figure 3 shows the track and chain with hangers (8-mm. eyebolt welded to every 10th and 22d link in the chain) for mounting the screen.

Tracking Unit

A track guided and supported the chain as it traveled between the sheaves (fig. 4). These tracks were greased liberally to reduce friction.

Screen Belt and Supports

The endless screen belt was constructed of spiral-wound carbon steel wire, like that commonly used in fireplace screens. The particular screen we used was 90-cm. wide, with 8-mm. openings and a 72-percent effective open area.

The screen was supported by flat-bar steel brackets, 3.2 mm. by 25.4 mm., bolted to its

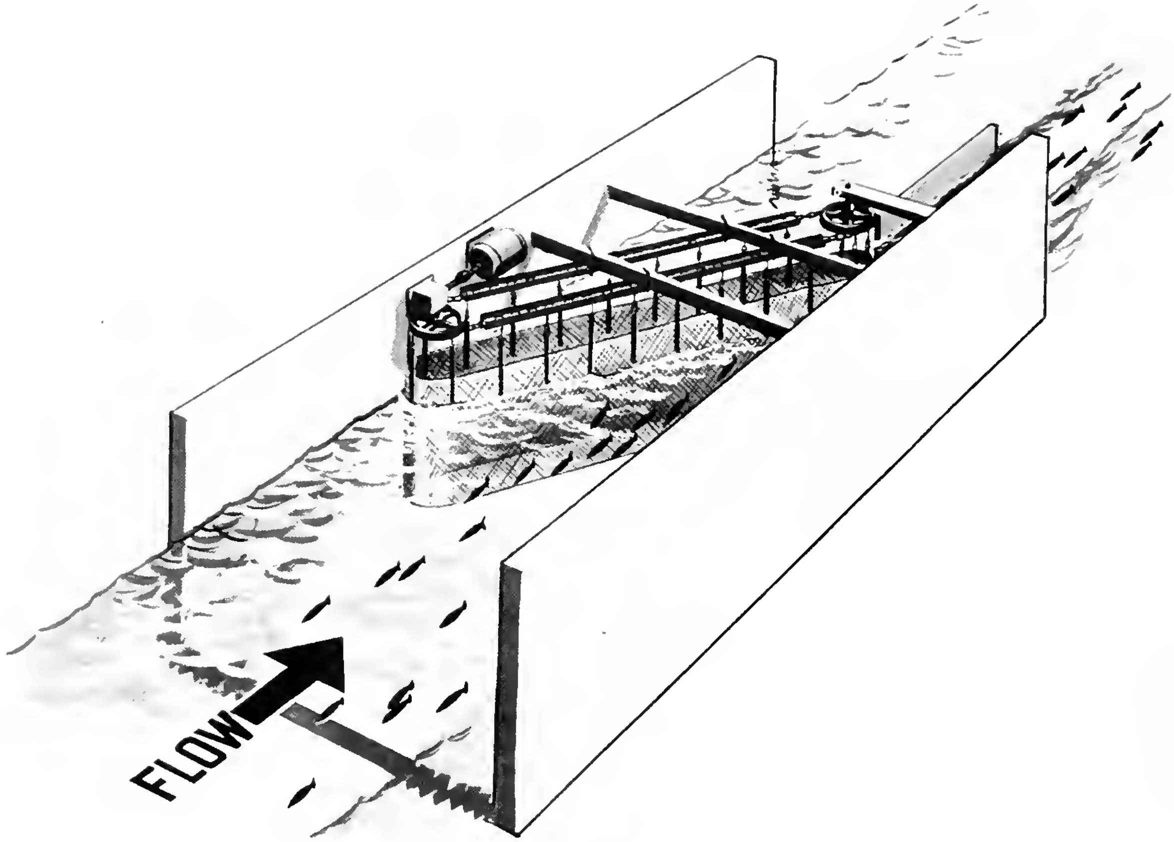

Figure 1.--Horizontal traveling screen, model 1.

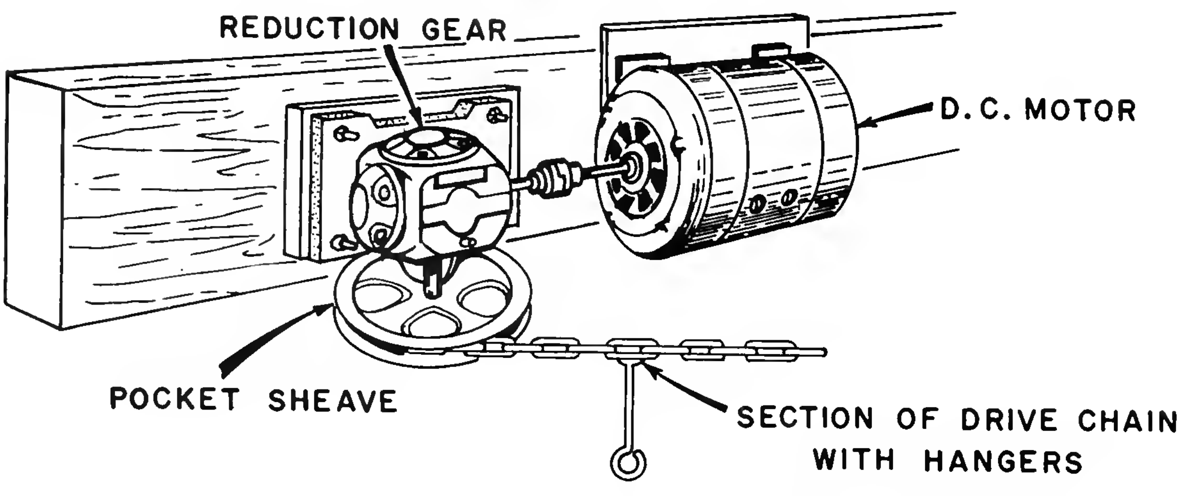

Figure 2.--Variable-speed d.c. motor and reduction gear drive assembly on traveling screen.

top edge at intervals corresponding to the hangers on the chain (fig. 4). Every fourth bracket extended to the bottom of the screen to serve as a stiffener. The brackets were attached to the drive chain with size 14, brass single-jack chain loops.

Additional support was provided by two stationary, horizontal rub-rails on the downstream side of the screen (fig. 4). The rub-rails, constructed of 25-mm. wide strap-iron, prevented the screen from being swept out of position by the flow. The rub-rail mounted on the floor also prevented fish from passing under the screen. The ends of the rub-rails were curved to eliminate the possibility of the screen becoming caught.

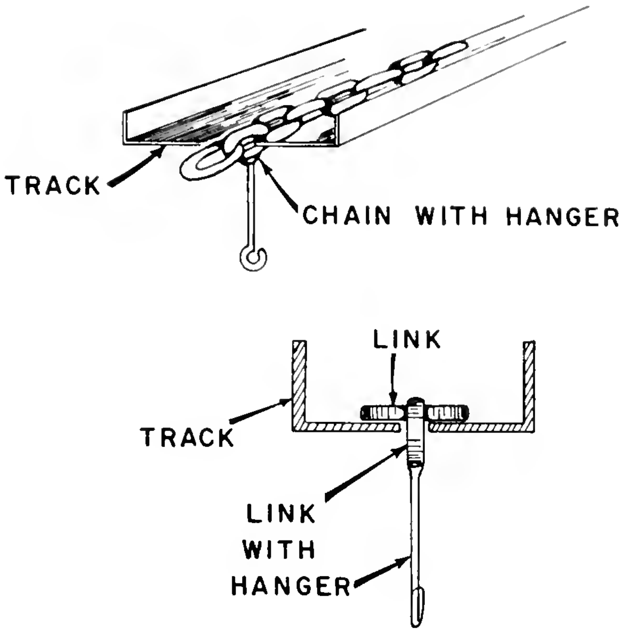

Figure 3.--Support and guide for the drive on the traveling screen.

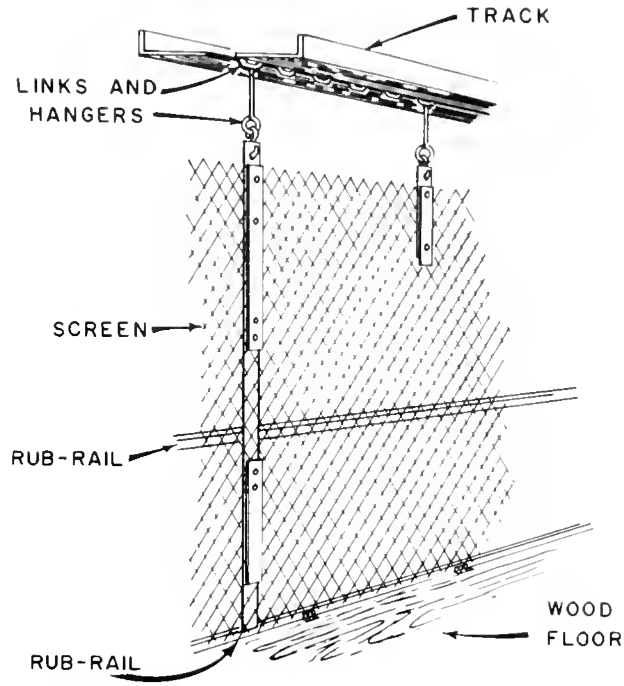

Figure 4.--Screen and 25-mm. flat bracket attachments.

OPERATION

Model I

Figure 5 shows a plan view of the first traveling screen. The continuous belt screen traveled from the upstream end (A) to the entrance of the bypass (B) at a 20° angle to the flow. This portion of the screen was supported by the two stationary rub-rails.

As the screen traveled from B to C it passed a rubber seal which formed a flexible joint between the bypass wall and the screen; the seal prevented loss of fish. To support the screen as it passed from B to C and to hold it against the rubber seal, two 18-cm. pulleys were mounted on a vertical shaft that extended from the downstream pocket sheave to the floor. The top pulley was 76 cm. from the floor; the other was 10 cm.

After it passed through the downstream seal, the screen traveled upstream against the current to point D, and around the upstream sheave, past another seal similar to the one downstream, to point A. Traveling at 1.5 m.p.s., the screen made a complete circuit in 5.5 seconds.

Model II

A second traveling screen was designed to eliminate the drag of the screen as it traveled through the water on its return upstream. This was accomplished by lifting the screen out of the water on its return upstream.

Figure 6 is a schematic drawing of model II. The screen traveled from the upstream end F to the downstream sheave G on a 20° angle to flow G. At point G the screen passed around a sheave and turned into the flume at

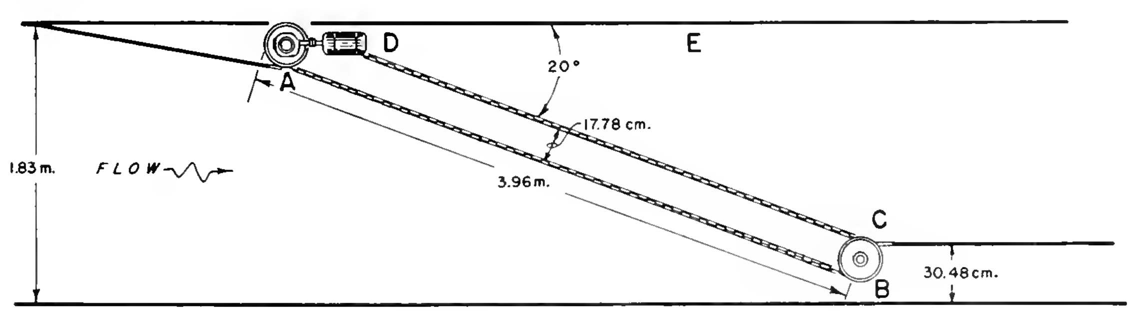

Figure 5.--Plan view of horizontal traveling screen, model I.

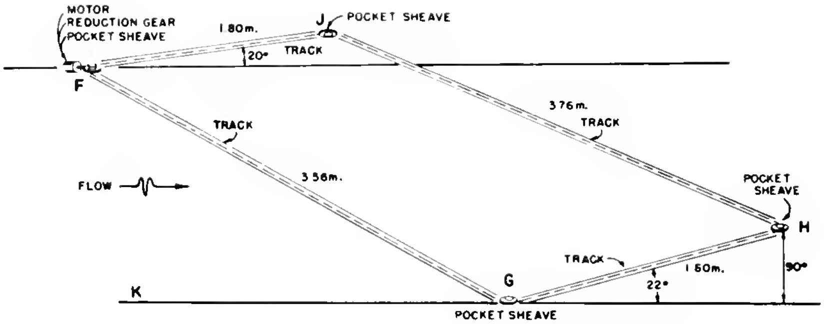

Figure 6.--Horizontal traveling screen, model II.

a 20° angle; the screen also began lifting at an angle of 22°. By the time the screen reached point H it had been lifted a distance of 61.0 cm. The screen traveled at this height from H to J, where it began descending. By the time it reached F, the bottom of the screen was again in contact with the floor.

Support for the leading face of the screen was identical to that on model I. A major difference between the two systems was that the drive unit and the tracking structure were sloped in model II to bring the screen out of the water for its travel upstream; all sheaves and the track were placed on the same 22° slope.

METHOD OF TESTING SCREEN

To test the traveling screen, we installed it in a flume at the Carson National Fish Hatchery near Carson, Wash., provided a bypass, and tested fish in this system.

Description of Flume

The basic structure consisted of a wooden flume (15.3 m. long, 1.8 m. wide, and 1.2 m. deep) set against the left bank of Carson Creek. A clear plastic window (1.1 m. by 1.8 m.) was installed near the downstream end of the flume to allow observation of response by the fish. Test fish introduced at the upstream end were recaptured at the downstream end of the flume by an inclined screen and trap with a perforated plate. Water came from Tyee Springs, several hundred meters away, at a flow of 1.3 m.p.s., which could be directed completely, or in part, into the flume.

Bypass

A 30.5-cm.-wide bypass was constructed; it was equal to the water depth, with an acceleration of 135 percent of the approach velocity to ensure acceptance by the fish.

Test Fish

Test fish were hatchery-reared spring chinook salmon, 8.9 to 15.3 cm. long, and coho salmon, 5.1 to 7.6 cm. long. The fish were dip-netted from a raceway and transported in containers to the upstream end of the flume. Water velocities tested were 1.0, 0.8, and 0.5 m.p.s. All the fish that migrated down the flume were guided by the screen into the bypass and swept over an inclined screen into a trap.

EFFICIENCY OF THE SCREEN

Placement of the traveling screen units at a small (20°) angle to the flow enabled the young fish to move into the bypass without becoming impinged against the screen.

All of the chinook and coho salmon tested at velocities of 0.5, 0.8, and 1.0 m.p.s. were guided into the bypass and trap (table 1). These high efficiencies were due to the perfect operation of the sealing system (at either end and along the canal floor) and the small size of the screen mesh.

Loss of head across the screen was small for both models. The loss was higher on model I because the screen remained in the water during its return upstream. There was no indication that head loss could be reduced by increasing the speed of the screen.

To study the effect of debris on the traveling screen we threw grass, moss, leaves from

Table 1.--Summary of number of fish and number of tests run at different water velocities; all fish entered the bypass

Species	Water velocity (m.p.s.)					
	1.0		0.8		0.5	
	Fish	Tests	Fish	Tests	Fish	Tests
	Number	Number	Number	Number	Number	Number
Chinook salmon	1,790	5	1,537	4	2,326	8
Coho salmon...	1,407	5	1,838	6	2,143	9

trees, and twigs into the flume above the screen. When the travel rate of the screen was equal to the velocity of the water, the debris was not forced into the meshes. As the screen turned away from the entrance to the bypass, material that had contacted the screen separated from it and entered the bypass.

Even though the two systems operated efficiently, we recognize that modifications in design will be required in a prototype facility.

ADVANTAGES OF THE SCREEN

On the basis of 2 years of operating the Carson Hatchery flume, we believe the traveling screen has certain advantages:

1. Operational efficiency of the facility remains high irrespective of fluctuations in depth of the water.
2. Higher allowable approach velocities are possible--if the fish were forced against the screen, they would be carried to the bypass and released.
3. Operational wear is potentially less than in industrial water screens, because all traveling units for support of the screen are above water.
4. The traveling screen is self-cleaning.
5. Loss of head is small in model II--only single screening is involved in contrast to double screening for the drum and industrial water screens.

The rate at which the screen moves depends on the amount of impingement, if any, and debris load. The rate must be adjusted so that small fish swept against the screen by the current will be carried into the bypass and released. Heavy debris loads could create loss of head and require faster travel to keep the screen clean.

In other systems, the juvenile migrants are either injured when dashed against drum screens and industrial water screens, or lost when swept through louvers. Migrants are not aided in reaching a bypass. Therefore, screens of existing systems require considerable attention during periods of turbulence and high velocity. In contrast, such conditions are of far less consequence when the traveling screen is used because the fish swept onto the screen are carried to the bypass and released.

This research has provided a basis for several new traveling screens which are either in the design stage or under construction. Engineering improvements have provided the cable-suspension systems to reduce installation costs, cantilevered stiff-legs to counter water pressure, relatively inexpensive but durable nylon netting, and more efficient track, carriage, and power-drive systems.

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1958. Research on guiding young salmon at two British Columbia field stations. Fish. Res. Bd. Can., Bull. 117, 75 pp.

MS. # 1846

Design and Operation of a Cantilevered Traveling Fish Screen (Model V)

By

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ABSTRACT

Model V was installed within the Stanfield Irrigation Canal near Echo, Oreg. The Bureau of Commercial Fisheries developed the screen to meet the need for improved guiding of juvenile fish of all sizes and to reduce capital and operational costs.

Field tests with the model V screen showed a head loss of only 9.1 mm. with waterflow of 73 centimeters per second. From 97 to 100 percent of the juvenile migrant coho salmon, Oncorhynchus kisutch, and steelhead trout, Salmo gairdneri, that entered the Stanfield Irrigation Canal were diverted into a bypass.

The self-cleaning screen, supported by a wire-rope suspension system, traverses the 8.5-m. wide, 1.8m. deep, earth-lined section of the canal at a 20° angle to the waterflow. Torsion induced in the structure by water forces on the screen is resisted by a main torque tube with track support arms placed at intervals along the tube. The support arms are tied with wire rope to anchors on shore. To minimize drag, the speed of the screen in the water can be matched to water velocity and the screen returned upstream above the water. Screen panels are cantilevered from carriers on a continuous track.

INTRODUCTION

The prototype-size traveling screen discussed here (model V) was placed in an earth-lined section of the Stanfield Irrigation Canal (a diversion of the Umatilla River) near Echo, Oreg. (fig. 1). Here it was exposed to the debris in the river and to the runs of juvenile steelhead trout, Salmo gairdneri, and coho salmon, Oncorhynchus kisutch, that had been drawn into the canal. The canal at the installation site was 8.5 m. wide and 1.8 m. deep. Flow discharges were 3.7 to 4.3 c.m.s. (cubic meters per second). The only modification in the canal floor was the construction of a 611-cm. wide concrete sill. The traveling screen was placed on a 20° angle to the direction of flow; it extended 23.2 m. across the canal.

The use of a wire-rope suspension system in place of piers is generally considered less costly. To demonstrate the practicability of this type of support system in rivers, the wire-rope suspension system was adapted at Stanfield.

This report describes: the design and operation of a traveling screen in which screen drag is reduced by lifting the panels out of the water before their return upstream and the results of mechanical and biological tests (trials with coho salmon and steelhead trout) of the system.

DESCRIPTION OF TRAVELING SCREEN

The structural and mechanical design of this screen was based on loading values in which consideration was given to the material from which the screen was constructed--19-gage, spiral-wound, carbon steel wire with 6.35-mm. openings and a 68-percent effective open area. The loading values were:

Wind load on screen--48 kg. per square meter (10 lb. per square foot)

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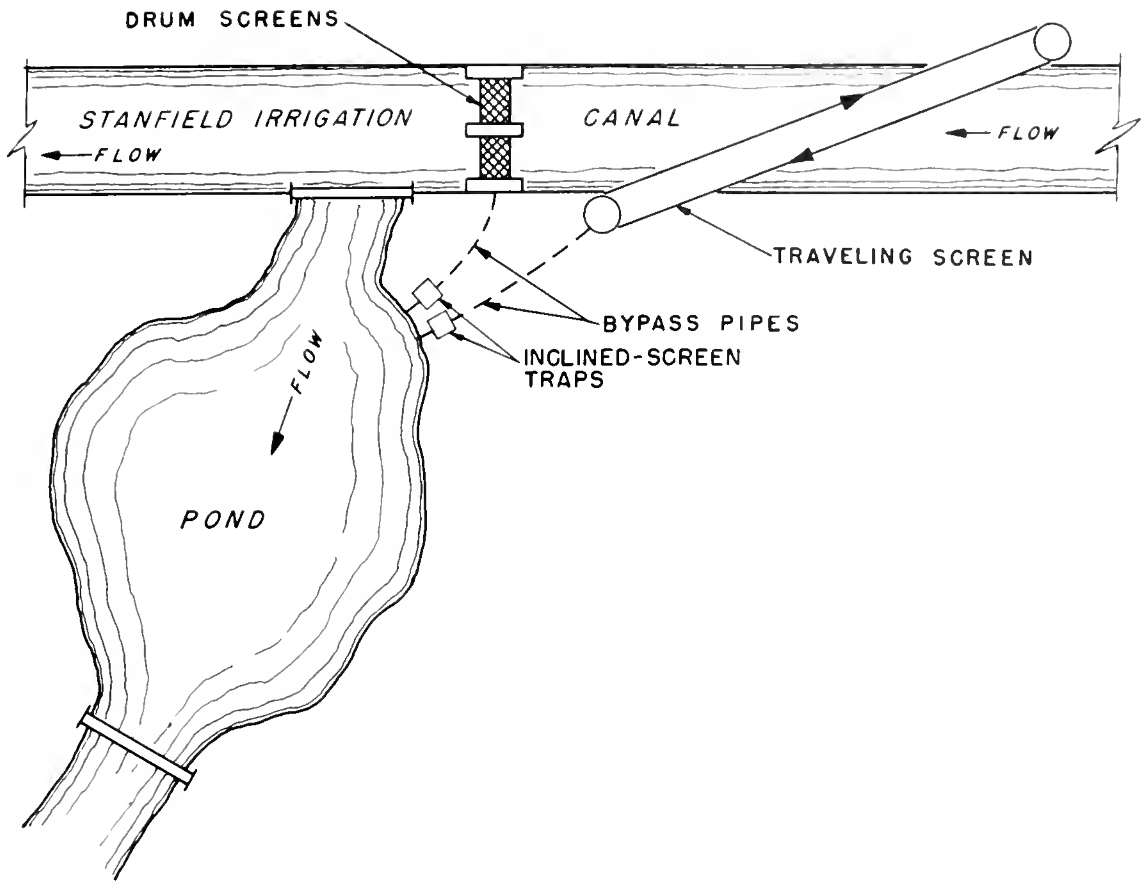

Figure 1.--Map showing location of Stanfield traveling screen.

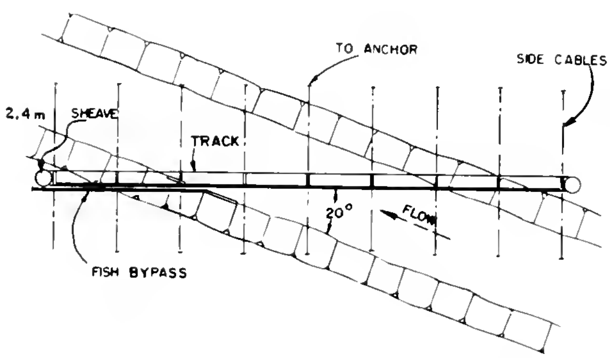

Figure 2.--Plan view of Stanfield traveling screen.

Water load on screen--34 kg. per square meter (7 lb. per square foot)

Water velocity--1.8 m. per second (6 ft. per second)

Uniform live load on structure--146 kg. per meter (100 lb. per foot). Water and wind-drag loads on screen elements were determined by varying water and air velocities and screen travel speeds.

The screen was placed at a relatively small angle (20°) to the direction of flow (fig. 2) to reduce the water pressure, or loading, on the screen and to prevent impingement of small coho salmon (minimum length, 37 mm.) that were used to test the efficiency of the deflection system. The fish approached the screen tail first and were deflected to one side when the water velocity was not too great. They headed generally into the flow and were carried downstream by the force of velocity. When the water velocity exceeded their swimming speed, or was faster than 46 cm.p.s. (centimeters per second), the salmon positioned themselves at an angle of 90° to the face of the screen. In this position, somewhat broadside to flow, they needed to swim at only 26 cm.p.s. to avoid impingement. Had the screen been placed at a 30° angle to flow with an approach velocity of 107 cm.p.s., the fish would have had to swim at about 40 cm.p.s. to remain free of the screen. Selection of the 20° angle, in this situation, made it easier for the fish to orient to the face of the screen.

Structural Design

The structural portion of the screen provides the support system for the traveling or

mechanical members and includes the suspension assembly, the torque tube and cables, and the track.

Suspension system.--To obtain a supporting structure that could be installed readily on a wide channel without need for expensive piers in the water, a suspension system was used. The main system (fig. 3) consists of a single 28.1-mm. diameter preformed steel cable with six strands, each composed of 19 wires. This cable is suspended a distance of 34.7 m. between two support towers, 4.9 m. high. The towers on both banks are constructed of 15-cm. standard weight pipe. Backstays of wire rope, extending out and in line with the traveling screen, assist in holding the support towers in a vertical position. Additional support is provided by transverse wire ropes extending perpendicular to the direction of the main cable. Each of these side cables (fig. 2) is attached on the ground to a concrete anchor.

Torque tube and cables.--The torque tube (fig. 4) functions as a stiffener element to minimize deformation of the cable from moving loads or nonuniform water pressures. It is formed of 7-gage steel, 20.3 cm. in diameter, and runs directly below the main cable from tower to tower.

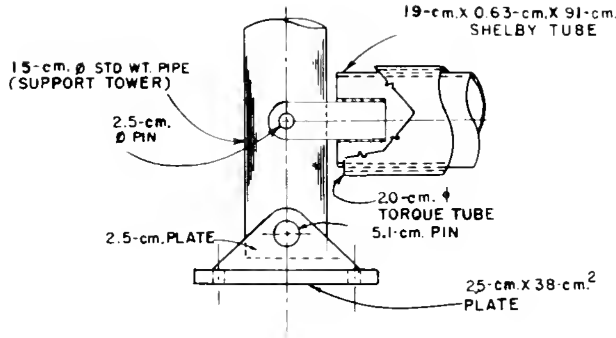

Figure 4.--Connection detail for torque tube and support tower.

The torque tube is given vertical support at 6.1-m. intervals by 9.5-mm. suspender cables. Turnbuckles in the suspender cables provide for adjustment of the vertical alignment of the torque tube. Horizontal and vertical loads, imposed on the track support assembly by the walkway and screen, are carried by the torque tube (fig. 5). The torque tube is therefore subjected to shear, torque, and bending. Side cables and torque cables form a couple to oppose these forces.

The side cables extend horizontally from each side of the torque tube at 6.1-m. intervals to anchors on the shore. These cables take

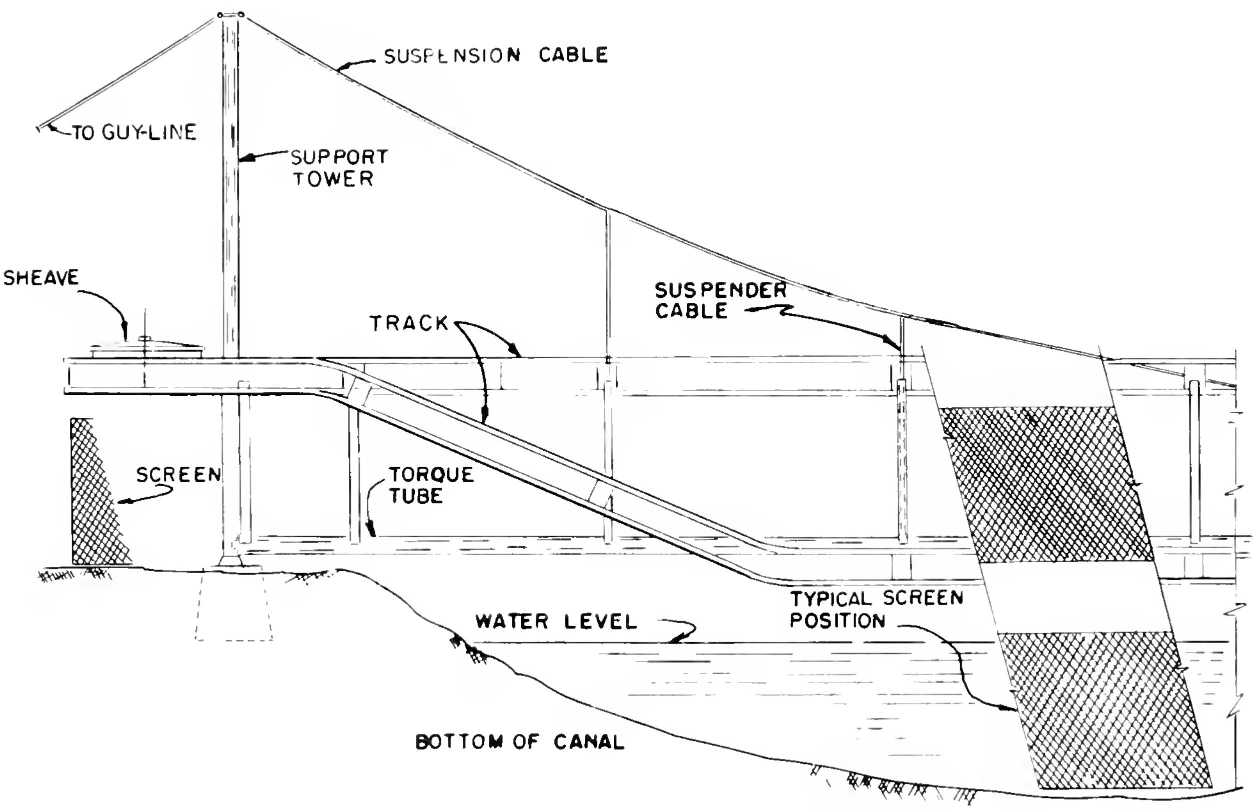

Figure 3.--Typical section of traveling screen deflector.

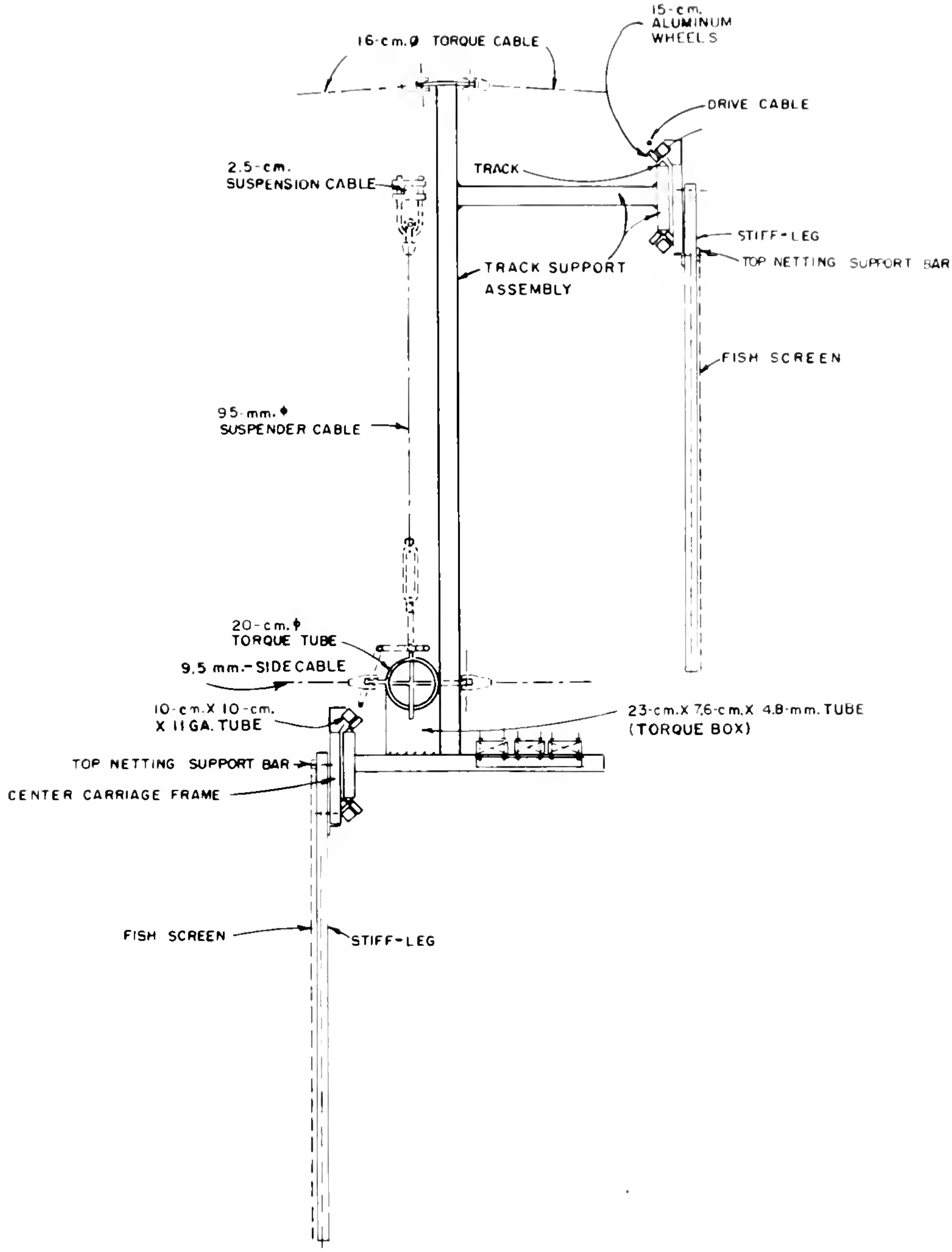

Figure 5.--Diagrammatic cross section of deflector and supporting structure.

the transverse loads on the suspension structure caused by the water and wind load on the structure and screens. The side cables consist of 9.5-mm. zinc-coated 6-7 wire strand core ropes. Turnbuckles in each cable allow adjustment of the horizontal alignment of the torque tube and the cable tension.

The torque cables extend horizontally from each side of the track support arms, spaced at 6.1-m. intervals to anchors on the shore. Torque cables consist of 15.9-mm. zinc-coated 6-7 strand core rope. Turnbuckles provide for adjustment of cable tension.

Track design and support.--The track system, 78.0 m. in circumference (fig. 6), is composed of a "V" track section formed of 5.1- by 5.1-cm. angle steel, 3.2 mm. thick, welded openside down to the top surface of the track support assembly. This provides the 45° angular running surface for the carriage wheels.

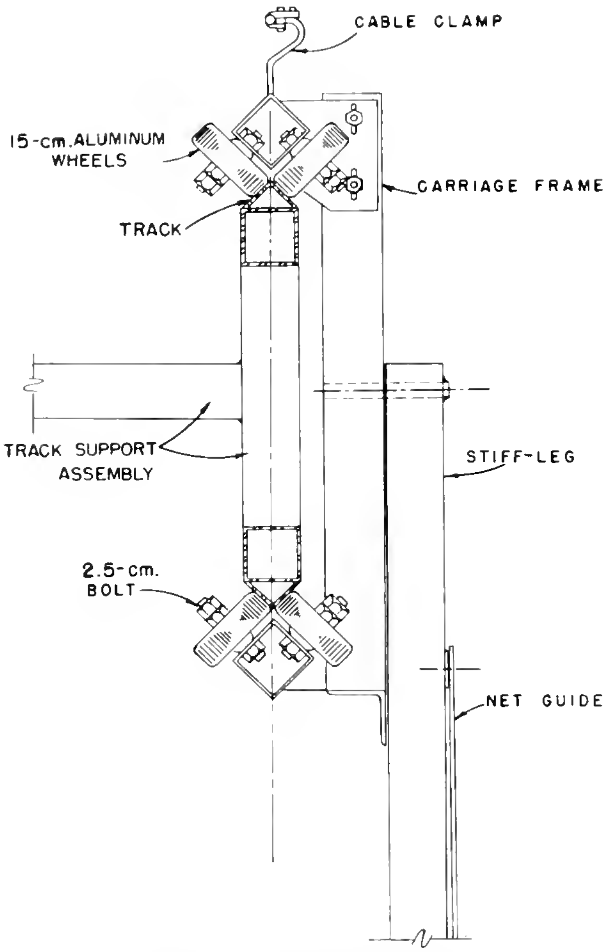

Figure 6.--Diagrammatic cross section of track, carriage, and cable clamp.

In the track configuration (fig. 7), the route from A to B is straight and follows the bottom of the canal, a distance of 12.80 m. The track from B to C rises on a 15° incline, a distance of 7.15 m. The track then runs 4.27 m. horizontally from C to D; it then forms a 2.36-m. semicircle from D to E. From E to F the track is straight, a distance of 36.27 m. From F to G it forms another 2.36-m. long semicircle leading onto a short 2.13-m. horizontal stretch, G to H. From H to A the track drops along a distance of 10.67 m. on a 10° slope.

Mechanical Aspects

The mechanical design includes all traveling assemblies such as the power-drive units, the bullwheels or sheaves, haul-line or traction line, carriages and cable-connectors, stiff-legs, and manner of net attachment.

Drive system.--The downstream drive unit is run by a 1.5-hp. gear motor with a sprocket attached to the drive shaft. The sprocket rotates in the mesh of a No. 60 roller chain attached to the inside perimeter of a 10.2-cm. wide, flat-bar ring, welded to the underside of the bullwheel. Variable speed control is provided.

A hydraulic drive system powers the upstream bullwheel. The assembly includes a 2.5-hp. hydraulic pump, which forces oil under high pressure into an orbit motor. The motor in turn drives a small pneumatic wheel, positioned against a vertical ring of the bullwheel. An oil pressure valve controls rate of travel.

Bullwheels.--The bullwheel design was patterned after those on conventional ski-tow systems. Bullwheels, 1.22 m. in diameter, were originally given serious consideration but would have required 54 carriages (the smaller the bullwheel diameter, the greater the number of carriages required). The selection of a 2.36-m. diameter bullhead reduced the number of carriages to 29.

Haul-line.--The haul-line was formed of a 22.3-mm. diameter, regular lay, 6-25 wire, hemp core rope. Six strands, each composed of 25 wires, gave flexibility and resistance to abrasion. The haul-line was connected directly to the carriages (fig. 8).

A system for adjusting the tension of the haul-line was provided.

Screen Support System

Carriages.--Carriages bore the weight of the individual net panels; each of the 29 carriages had eight 15.24-cm. aluminum wheels. Each wheel had a tread of polyurethane and an automotive-type bearing and was positioned to travel on the flat sides of the 45° angle track (fig. 9). Preliminary tests indicate that the number of wheels in each carriage may be reduced without loss in efficiency.

Stiff-legs.--Each carriage frame was fitted with a centrally mounted, 2.44-m. long cantilever swing tube, or stiff-leg, 3.81 cm. by 7.62 cm., 16-gage. The ability of the tube to swing in the direction of travel allows the screen to form a rectangle or parallelogram, depending upon which section of the track is being traversed. The pivot point is at the top of the stiff-leg and the center of the carriage, thereby equalizing net strains (skewing) along the vertical curves of the track. Cantilevers are fastened, top and bottom, by horizontal metal tubing to form a frame for net attachment.

Netting and attachment.--All experimental traveling screens (before construction of the Stanfield facility) had been successfully

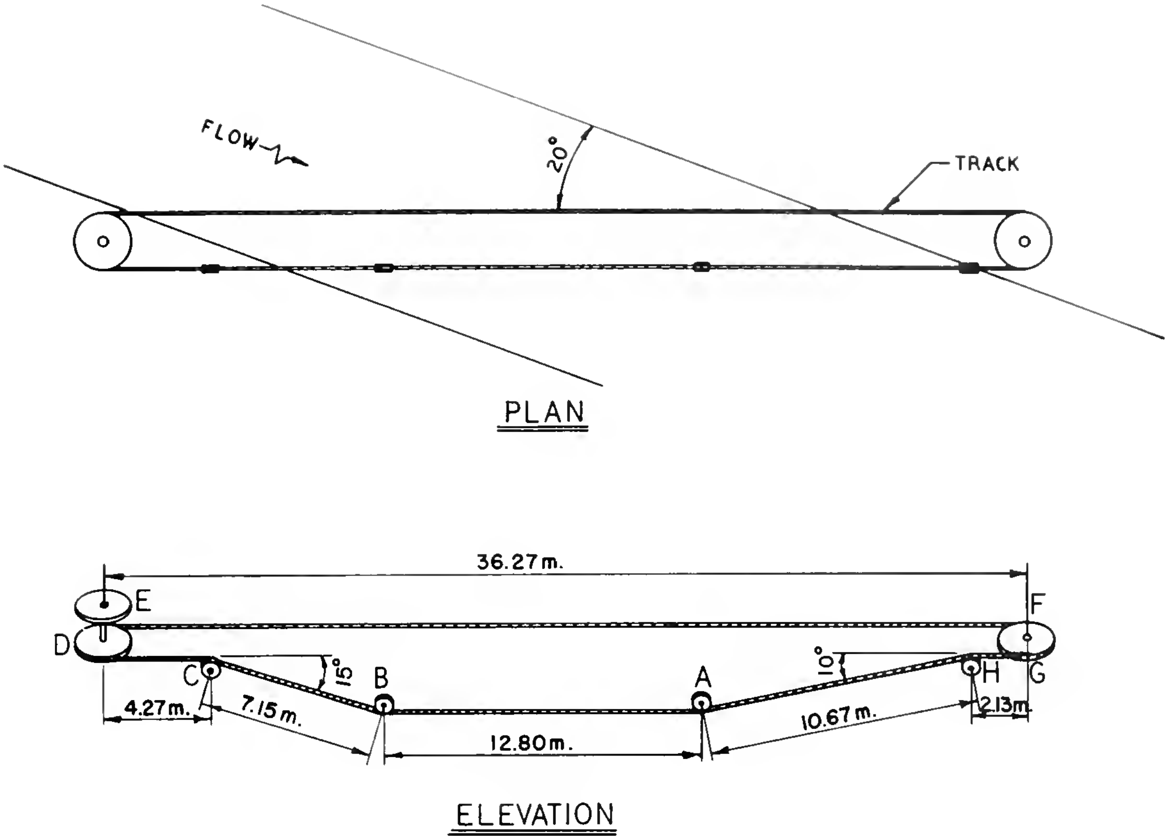

Figure 7.--Track arrangement of traveling screen.

operated with a wire-cloth screen. With advances in design and fabrication of nylon netting, however, we considered it necessary to test its durability, head loss, and the relation of mesh size to efficiency of screening fish. Without exception, each of the nylon net materials tested demonstrated an unusual ability to withstand physical and chemical deterioration.

On the basis of the success of these tests, we selected a 12.7-mm. stretched nylon net (No. 50), manufactured by the Linen Thread Company of Blue Mountain, Ala.[3] The netting (twine diameter, 1.02 mm.) had an effective open area of 72 percent. To attach the net panels to the stiff-legs, a bulblike border was formed along all four sides of each net. This border in turn was fitted into specially designed slots on the vertical stiff-legs and horizontal connector tubes (fig. 10); about 5 minutes were required to replace a net panel.

An open space of about 7.62 cm. was intentionally left between the concrete sill on the canal floor and the bottom of the traveling screen to prevent contact between the bottom of the stiff-legs and netting. To prevent fish from passing through this opening, a sealing system was provided by vertical attachment of a flexible 15-gage wire-cloth screen (used normally as conveyor belting) to the underside of each panel. During operation of the panel, the wire-cloth screen effectively sealed the opening, remained clear of moss and grass, and provided the flexibility and durability needed.

Bypass Design

A 1.8-m. deep and 61-cm. wide bypass was placed in line with the direction of screen travel to accommodate the screen as it traveled up and out of the water. When traveling screens are not raised out of the water (models VI and VII), the bypass can be placed in line with the direction of waterflow as with louvers. Flow within the bypass was controlled with an electrically operated watergate.

OPERATION OF TRAVELING SCREEN

We evaluated the efficiency of the traveling screen in five specific areas: (1) rate of screen travel, (2) head loss, (3) deflection efficiency, (4) self-cleaning capabilities, and (5) bypass.

[3] Trade names referred to in this publication do not imply endorsement of commercial products by the Bureau of Commercial Fisheries.

Figure 8.--Connector between haul-line and carriage.

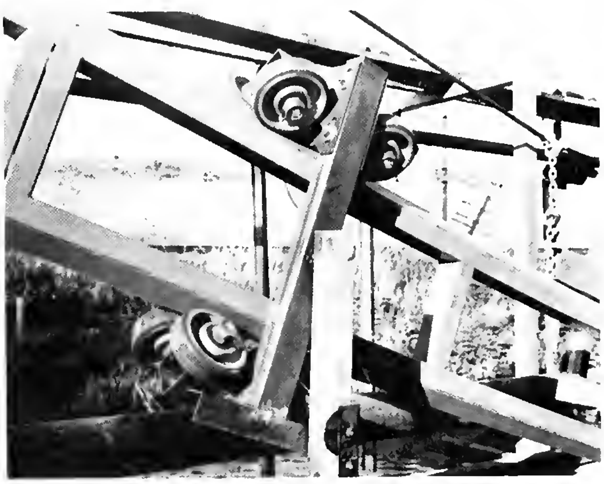

Figure 9.--Track and carriage at point of stiff-leg attachment.

Rate of Travel

The velocity at which the screen should be moved depends on the extent of impingement, if any, and of accumulation of debris. Impingement, should it occur, would require screen travel at a rate suitable to carry the fish into the bypass. Accumulation of debris on the screen increases head loss and necessitates rates of travel that provide for cleaning of the screen. Because neither impingement nor accumulation of debris was apparent at Stanfield, the screen was usually moved at a rate of only 40 cm.p.s.

We have not determined whether the rate of travel of the screen influences the degree of head loss against the structure.

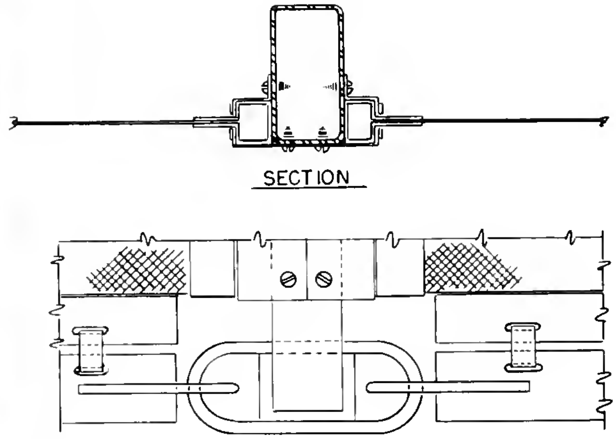

Figure 10.--Corner joint of screen panel.

Loss of Head

Loss of head occurs because the screening material forms a partial obstruction to the flow. Structural members, such as the stiff-legs, in addition to the debris, add to this loss. To determine head loss at Stanfield, water levels 1.2 m. upstream from the upper end of the traveling screen and 1.2 m. downstream from its lower end were measured. The difference between the two readings represented the head loss for the specific water velocity at the time. At a mean velocity of about 73.2 cm.p.s., with a nylon net of 12.7-mm. stretch nylon mesh (effective open area of 72 percent), the measurable head was only 9.14 mm.

Efficiency of Deflection

The traveling screen at Stanfield was installed early in June 1967 at the height of the downstream migration of juvenile coho salmon. We made a series of tests on the efficiency of deflection of juvenile coho salmon and steelhead trout in the canal. Water velocities varied between 61 and 91.5 cm.p.s. (mean 73.2 cm.p.s.), whereas the depth fluctuated between 1.68 and 1.83 m.

An inclined-screen trap placed at the downstream end of the bypass collected the fish deflected by the screen (fig. 1). Fish not deflected by the screen were trapped in the bypass of a drum-screen, a short distance downstream from the traveling screen.

Table 1.--Percentage deflection of coho salmon and steelhead trout by traveling screen of 12.7-mm. stretch nylon mesh placed at an angle of 20° with the water flow in Stanfield Canal, 1967

Date	Water temperature	Water velocity in the canal	Water velocity in the bypass compared with velocity in the canal	Test fish			
				Coho salmon		Steelhead trout	
				Fish used	Fish deflected	Fish used	Fish deflected
June	°C.	Cm./sec.	Percent	Number	Percent	Number	Percent
10	16.1	78.3	140	217	99	140	99
11	16.1	70.4	137	174	98	95	99
12	16.7	69.7	135	189	100	112	100
13	16.7	76.2	138	172	99	153	97
14	17.2	77.7	138	181	99	97	98
15	17.8	74.0	137	250	99	176	97
16	18.4	73.7	136	164	100	64	100
17	19.5	76.5	140	194	99	88	100
18	20.0	83.2	143	217	100	155	99
19	19.5	89.6	144	253	99	148	99
20	19.5	81.9	143	135	99	151	98
21	18.9	80.1	141	126	98	206	99
22	18.4	78.6	140	49	100	158	99
23	18.9	78.6	139	23	100	56	100

The curtain of continuously moving netting (12.7-mm. stretch nylon) deflected 97 to 100 percent of the young steelhead trout and coho salmon (table 1). Fish that were not deflected by the screen probably passed under the net near the point where it entered the water. This area was difficult to seal. In models VI and VII the screens will not be raised out of the water, and this problem will be eliminated.

Self-Cleaning Capabilities

The Stanfield screen represents the fifth experimental screen model;[3] common to all models is the capacity for self cleaning. This action results from a reverse flow through the net at the entrance to the bypass. Such a flow can be developed in different ways, depending on the design of each traveling screen. As yet, no supplementary cleaning system has been needed.

To prevent damage to the net by large pieces of debris, such as logs, a conventional trash-rack was installed within the Stanfield Canal just upstream from the traveling screen. The rack was constructed of 5.08- by 7.62-cm. metal tubes, spaced on 20.32-cm. centers.

[3] Each of the previous models, 1 through IV, represents in succession an advanced and improved design. Model VI, recently installed in the Troy, Oreg., test flume and capable of screening over 28 c.m.s. of water, has many design improvements such as a completely horizontal track (eliminating the screen lift-out feature), readily removable panels, and panels that open up on their return travel to reduce head loss. We will make additional design improvements in model VII, now being designed for the Leaburg Canal, Eugene, Oreg.

Handling large debris, such as logs, will be more difficult in situations that may require screening of large volumes of water--30 c.m.s. or more. In recognition of this problem, we developed and tested a traveling debris net at another test site.[4] The tests indicated that logs 6 m. long and 1 m. in diameter (with limbs attached and weighing over 1,000 kg.) could, after being swept onto the cable-formed screen, be carried easily and rapidly into a quiet pond for removal by conveyor.

Bypass

Whatever the success in fish deflection by any screen, it could be readily nullified by inefficient bypass operation. To secure satisfactory results, two basic factors must be considered: The first involves adequacy of bypass width. To ensure fish acceptance of the model V bypass, the width was set at 0.61 m. which is generally considered by biologists (Ruggles, 1964) to be the maximum required.

The second bypass factor concerns the velocity relation of the bypass flow to the main canal flow. A bypass velocity of about 140 percent of the approach velocity is suggested (Bates and Vinsonhaler, 1957). Any reduction of velocity within the bypass causes the fish to either hesitate or refuse the bypass completely.

[4] Bates, D. W., E. W. Murphey, and M. J. Beam. Traveling net for removal of water-borne debris from rivers. U.S. Fish Wildl. Serv., Bur. Commer. Fish. Biol. Lab., Seattle, Wash. [Manuscript.]

Based on the individual response (underwater observations) of 492 juvenile steelhead trout and 151 young coho fry, with an approach to bypass water velocity of 1 to 1.4 (140 percent), only 7 percent of the steelhead (34 fish) and 2 percent of the coho (3 fish) showed any hesitation in accepting the bypass. The steelhead generally passed into the bypass individually or in small groups of up to five. The cohos moved through generally singly or in groups of two to three, possibly having broken away from a larger school at the intake of the diversion canal.

EFFECTIVENESS OF TRAVELING SCREEN

The most important feature in the development of the traveling screen has been the near elimination of a wide range of problems previously encountered with all other systems in the diversion and collection of juvenile fish. For example, juvenile migrants carried onto louvers are swept through and lost; those carried onto industrial water screens or drum screens could be injured or killed because of turbulent flow. These types of screens in no way assist the migrants in their efforts to reach the bypass. In contrast, fish swept onto a traveling screen are effectively carried into the bypass.

Another unusual and important advantage of a traveling screen is its potential capacity to collect eggs and weak, free-swimming larvae and fry and to move them directly into the safety of the bypass. As the screen can be moved to match the velocity of the water, impingement of small fish and eggs is gradual and not damaging. Furthermore, the operating effectiveness of the traveling screen is not altered by extreme fluctuation of water level.

SUMMARY

An improved traveling screen for diverting juvenile migrants from rivers, streams, and canals was developed in 1965-67. This structure, model V, was tested during the spring of 1968 within the 8.53-m. wide Stanfield Irrigation Canal, a diversion of the Umatilla River near Echo, Oreg. The screen, which hangs vertically, traverses the canal at an angle of 20° to waterflow and returns above water to minimize drag. The weight of the screen and the water pressure against it are supported by a wire-rope suspension structure.

The main suspension structure consists of a single main wire rope between two end towers. Suspenders from the main wire rope carry a 20.3-cm. diameter pipe (the torque tube), which acts as a longitudinal stiffening member and as a base for mounting equipment.

Side-wire ropes projecting at right angles to the pipe are attached to anchors along the canal bank. These side-wire ropes take the lateral loads, imposed on the pipe beam by water pressures and by wind on the return journey.

Water and wind acting on the screen create a torque on the pipe beam element. This torque is resisted by the couples formed by the side-wire ropes and the torque wire ropes. The torque wire ropes are attached to the return screen support arm and fastened to anchors.

The screen is supported from traveling carriers, fitted with a cantilever swing tube that allows the screen to form a rectangle or parallelogram, depending upon which section of the track is being traversed. Cantilevers are tied together--top and bottom--by tubing to form a frame. The screen panels are formed with a rubber bulb for attachment to the frame.

The carriers are driven by a gear motor driving the take-up sheave through a spocket and roller chain. This sheave in turn drives a wire-rope, attached to the carriers through a special slip.

Operation of the traveling screen requires such considerations as rate of travel, head loss, fish deflection, and bypass flow. The Stanfield screen was usually moved at a velocity of 40 cm.p.s.--a relatively slow rate due to small debris load and absence of impingement of fish.

Use of a 12.7-mm. stretched nylon mesh, with an extensive effective open area of 72 percent, caused a head loss of only 9.14 mm. at the low water velocity of 73 cm.p.s. The mesh was small enough to retain all fish.

The curtain of continuously moving netting deflected 97 to 100 percent of the young steelhead and coho salmon; the self-cleaning action of the screen was sufficient to keep the netting clean at all times regardless of amount or type of debris. During the operation of the traveling screen, velocity of water in the bypass was maintained at 140 percent of the mean velocity in the canal to insure acceptance by the young migrants.

Based on tests and 3 years' experience in operating the traveling screen, the following conclusions appear warranted: (1) use of the traveling screen in the deflection of young salmon and trout is practicable and desirable, (2) operational efficiency remains high even though water levels fluctuate, (3) it is possible to deflect fish when water velocities are high--if fish become impinged they are carried to and released directly within the bypass, (4) operational wear is reduced because all traveling units are above water, (5) correctly designed, the screen is self-cleaning, (6) head loss is small as only single-screening is involved in contrast to double-screening for many other systems, (7) individual net panels can be easily removed and replaced, and (8) the reduced need for supplementary

bypasses results in a very favorable ratio of bypass flow to total canal flow.

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